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Online:WPI,INSPEC

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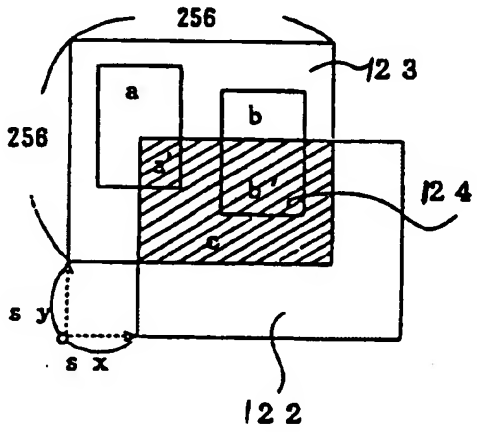
(54) **Fingerprint identification system**

(57) A fingerprint ID system, which compares input fingerprint image data with registered data scans input fingerprint image data, thins it and extracts minutiae bulge-line direction patterns and bulge-line curvature patterns are compared, and the matching degree between the fingerprint image data and the registered data is compared with two threshold values for judging if the examinee is the person of the registered data. When the matching degree is between the two thresholds, minutiae are compared successively in minutia high-density areas and minutia medium-density areas.

Fig.26



Best Available Copy

GB 2 310 522 A

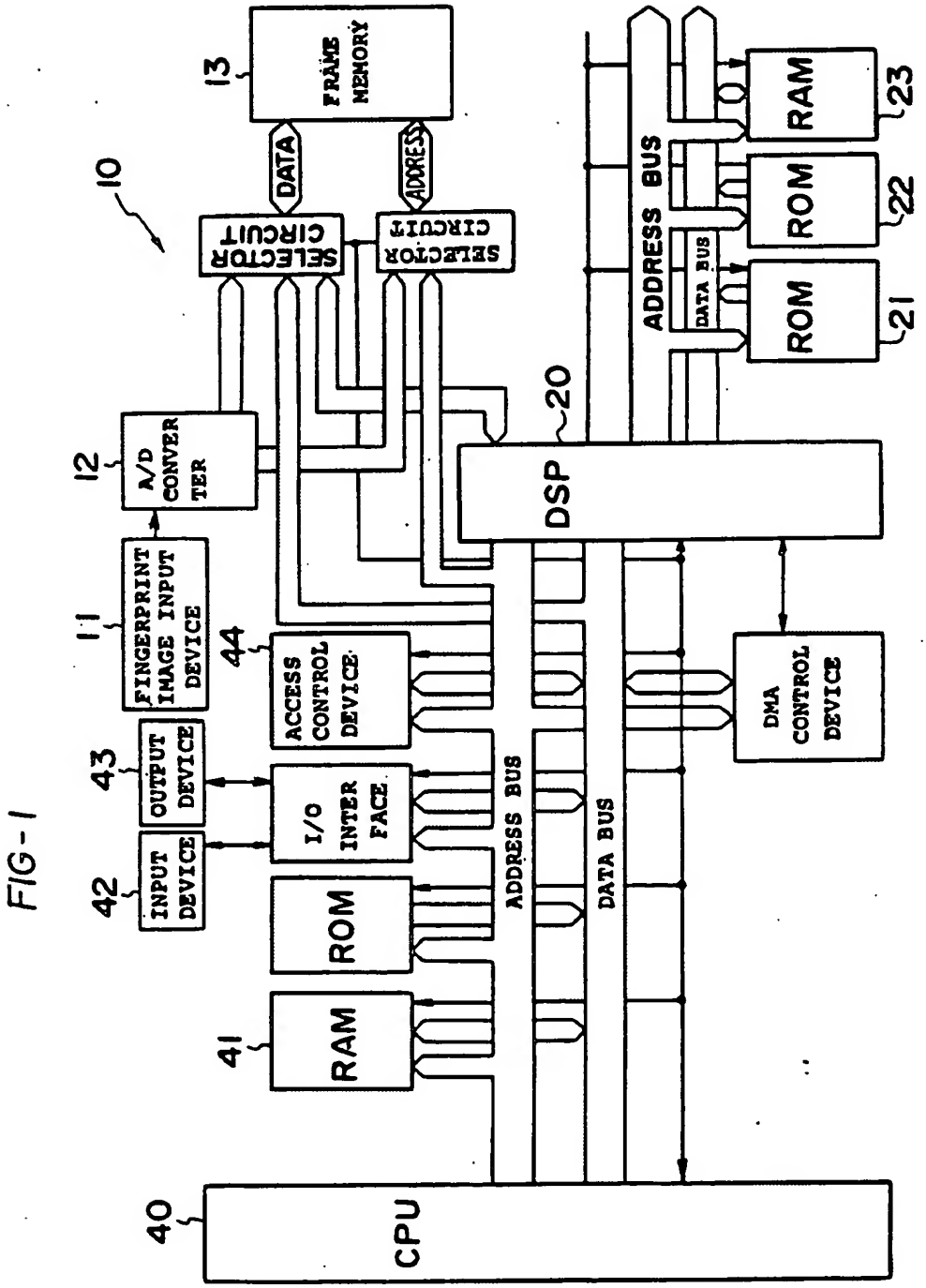

10
13
FRAME MEMORY
DATA
ADDRESS
SELECTOR CIRCUIT
SELECTOR CIRCUIT
12
A/D CONVERTER
11
FINGERPRINT IMAGE INPUT DEVICE
44
ACCESS CONTROL DEVICE
43
OUTPUT DEVICE
42
INPUT DEVICE
I/O INTERFACE
ROM
41
RAM
ADDRESS BUS
DATA BUS
20
DSP
ADDRESS BUS
DATA BUS
RAM
23
ROM
22
ROM
21
DMA CONTROL DEVICE
40
CPU

FIG-1

Fig. 2

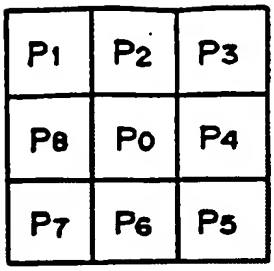


Fig. 3

0	3	6	7	10	11	12	14	15	22					
24	26	27	28	30	31	40	42	43	44					
46	47	48	56	58	59	60	62	63	96					
104	106	107	108	110	111	112	120	122	123					
124	126	127	129	130	131	134	135	138	139					
142	143	154	155	158	159	160	161	162	163					
166	167	168	169	172	173	176	177	178	179					
182	183	184	185	188	189	192	193	194	195					
198	199	202	203	206	207	218	219	222	223					
224	225	226	227	230	231	232	233	236	237					
240	241	242	243	246	247	248	249	252	253					

FIG - 4

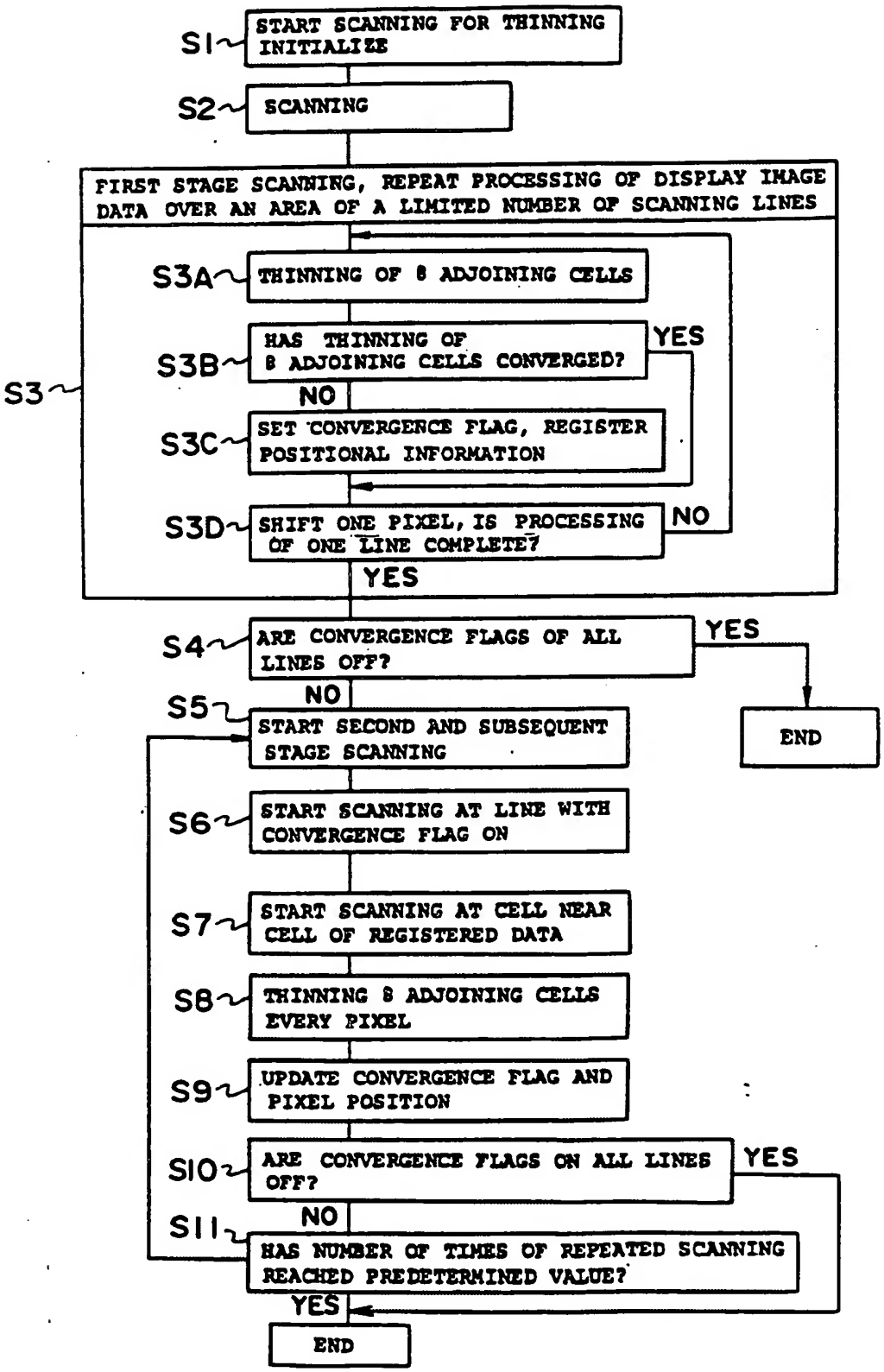
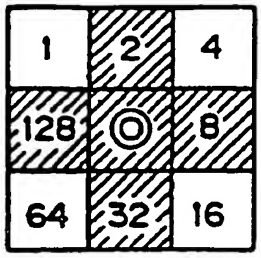

S1
START SCANNING FOR THINNING INITIALIZE
S2
SCANNING
FIRST STAGE SCANNING, REPEAT PROCESSING OF DISPLAY IMAGE DATA OVER AN AREA OF A LIMITED NUMBER OF SCANNING LINES
S3
S3A
THINNING OF 8 ADJOINING CELLS
S3B
HAS THINNING OF 8 ADJOINING CELLS CONVERGED?
YES
NO
S3C
SET CONVERGENCE FLAG, REGISTER POSITIONAL INFORMATION
S3D
SHIFT ONE PIXEL, IS PROCESSING OF ONE LINE COMPLETE?
NO
YES
S4
ARE CONVERGENCE FLAGS OF ALL LINES OFF?
YES
NO
END
S5
START SECOND AND SUBSEQUENT STAGE SCANNING
S6
START SCANNING AT LINE WITH CONVERGENCE FLAG ON
S7
START SCANNING AT CELL NEAR CELL OF REGISTERED DATA
S8
THINNING 8 ADJOINING CELLS EVERY PIXEL
S9
UPDATE CONVERGENCE FLAG AND PIXEL POSITION
S10
ARE CONVERGENCE FLAGS ON ALL LINES OFF?
YES
NO
S11
HAS NUMBER OF TIMES OF REPEATED SCANNING REACHED PREDETERMINED VALUE?
YES
END

FIG-5

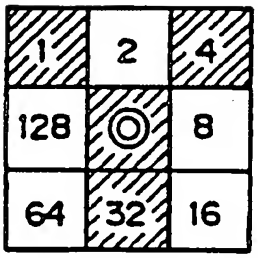
INTERSECTION	85 170
BRANCH POINT	21 37 41 69 73 74 81 82 84 146 148 164
END POINT	1 2 4 8 16 32 64 128

Fig. 6

(A)



(B)



(C)

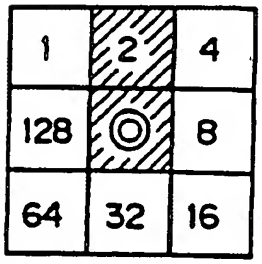
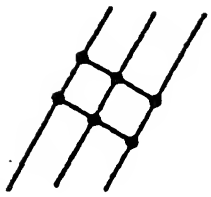


Fig. 7

(A)



(B)

(C)

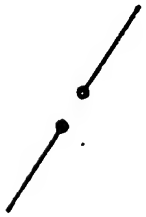


Fig. 8

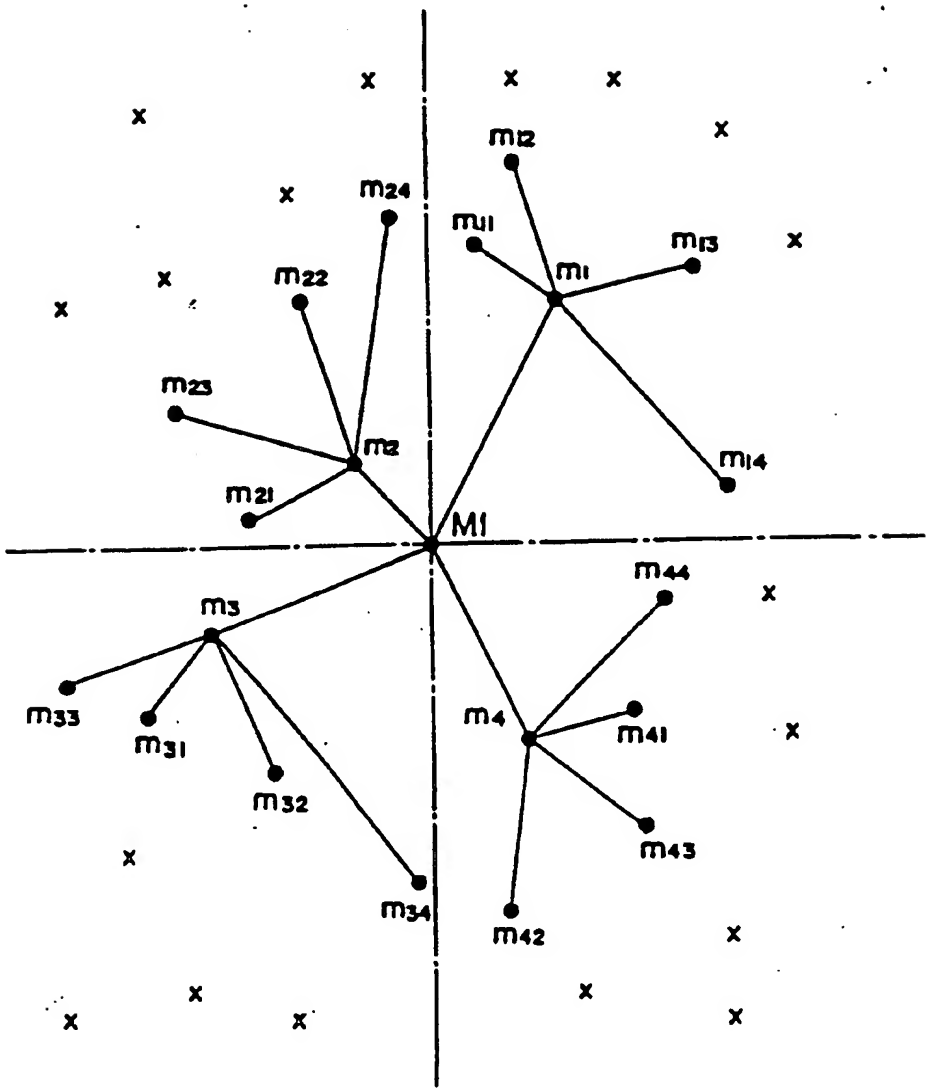

m12
m24
m11
m13
m1
m22
m23
m2
m14
m21
M1
m44
m3
m33
m4
m41
m31
m32
m43
m34
m42

Fig. 9

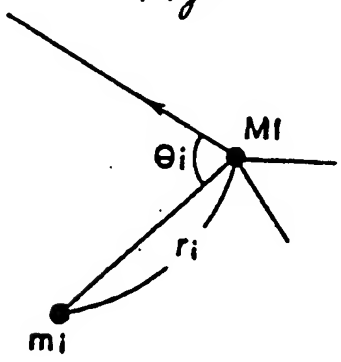

M1
θi
ri
mi

FIG-10

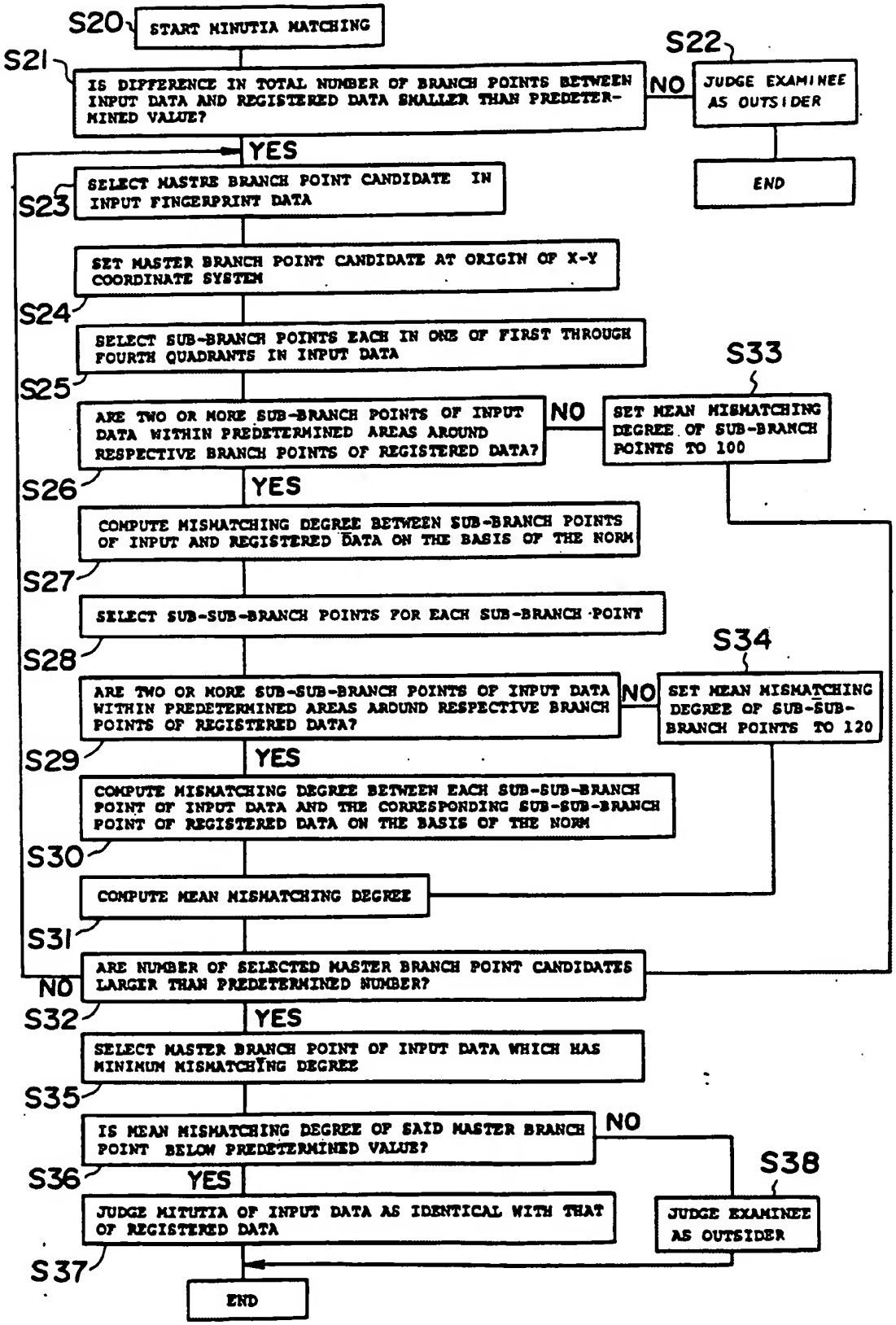

S20
START MINUTIA MATCHING
S21
IS DIFFERENCE IN TOTAL NUMBER OF BRANCH POINTS BETWEEN INPUT DATA AND REGISTERED DATA SMALLER THAN PREDETERMINED VALUE?
NO
S22
JUDGE EXAMINEE AS OUTSIDER
END
YES
S23
SELECT MASTRE BRANCH POINT CANDIDATE IN INPUT FINGERPRINT DATA
SET MASTER BRANCH POINT CANDIDATE AT ORIGIN OF X-Y COORDINATE SYSTEM
S24
SELECT SUB-BRANCH POINTS EACH IN ONE OF FIRST THROUGH FOURTH QUADRANTS IN INPUT DATA
S25
ARE TWO OR MORE SUB-BRANCH POINTS OF INPUT DATA WITHIN PREDETERMINED AREAS AROUND RESPECTIVE BRANCH POINTS OF REGISTERED DATA?
NO
S33
SET MEAN MISMATCHING DEGREE OF SUB-BRANCH POINTS TO 100
S26
YES
COMPUTE MISMATCHING DEGREE BETWEEN SUB-BRANCH POINTS OF INPUT AND REGISTERED DATA ON THE BASIS OF THE NORM
S27
SELECT SUB-SUB-BRANCH POINTS FOR EACH SUB-BRANCH POINT
S28
ARE TWO OR MORE SUB-SUB-BRANCH POINTS OF INPUT DATA WITHIN PREDETERMINED AREAS ARDUND RESPECTIVE BRANCH POINTS OF REGISTERED DATA?
NO
S34
SET MEAN MISMATCHING DEGREE OF SUB-SUB-BRANCH POINTS TO 120
S29
YES
COMPUTE MISMATCHING DEGREE BETWEEN EACH SUB-SUB-BRANCH POINT OF INPUT DATA AND THE CORRESPONDING SUB-SUB-BRANCH POINT OF REGISTERED DATA ON THE BASIS OF THE NORM
S30
COMPUTE MEAN MISMATCHING DEGREE
S31
ARE NUMBER OF SELECTED MASTER BRANCH POINT CANDIDATES LARGER THAN PREDETERMINED NUMBER?
NO
S32
YES
SELECT MASTER BRANCH POINT OF INPUT DATA WHICH HAS MINIMUM MISMATCHING DEGREE
S35
IS MEAN MISMATCHING DEGREE OF SAID MASTER BRANCH POINT BELOW PREDETERMINED VALUE?
NO
S38
S36
YES
JUDGE MITUTIA OF INPUT DATA AS IDENTICAL WITH THAT OF REGISTERED DATA
JUDGE EXAMINEE AS OUTSIDER
S37
END

Fig. 11

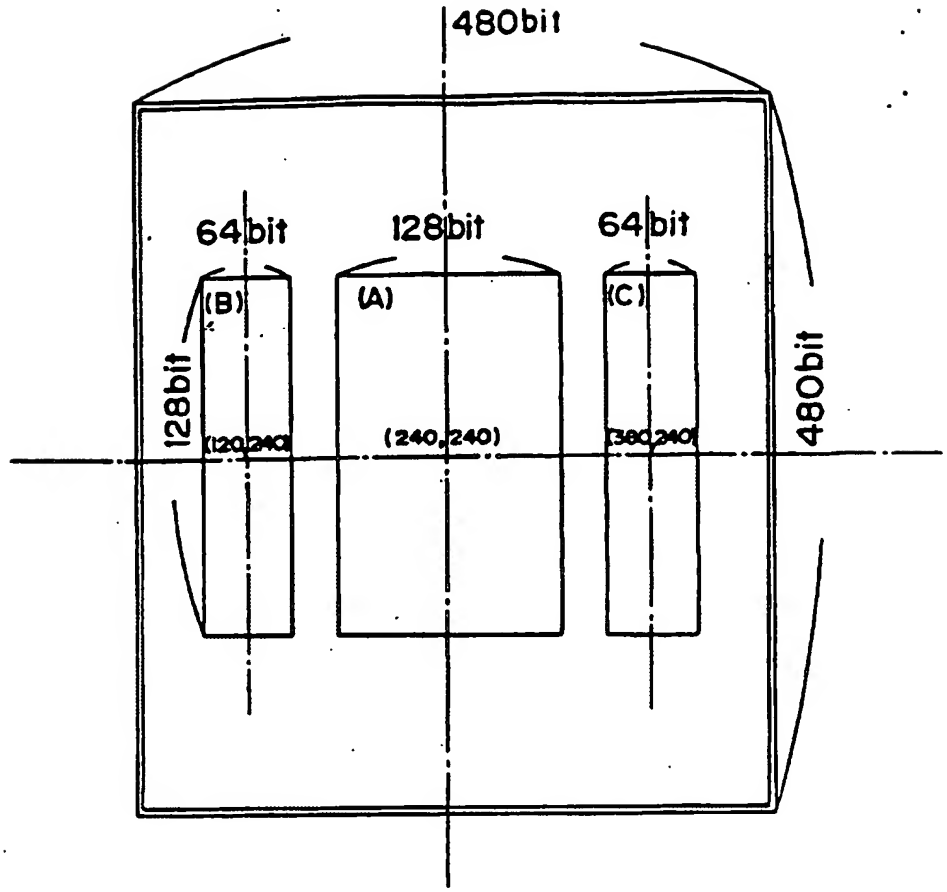

480bit
64bit
128bit
64bit
(B)
(A)
(C)
128bit
480bit
(120,240)
(240,240)
(360,240)

FIG- 12

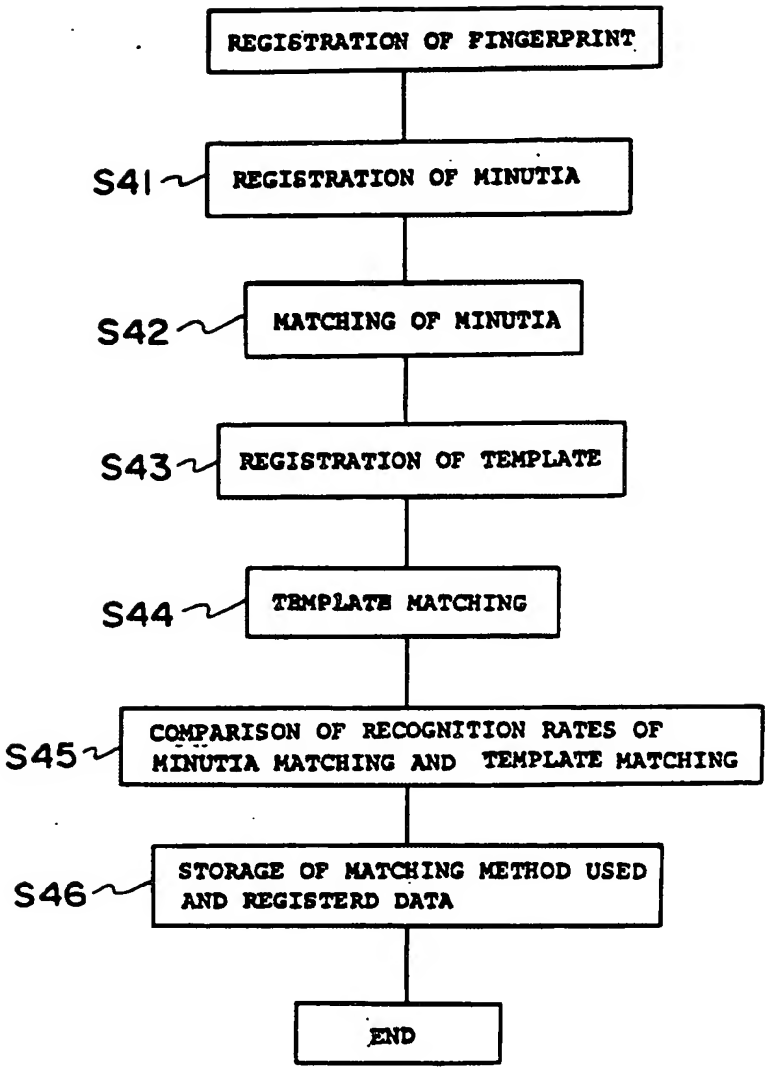

REGISTRATION OF FINGERPRINT
S41
REGISTRATION OF MINUTIA
S42
MATCHING OF MINUTIA
S43
REGISTRATION OF TEMPLATE
S44
TEMPLATE MATCHING
S45
COMPARISON OF RECOGNITION RATES OF MINUTIA MATCHING AND TEMPLATE MATCHING
S46
STORAGE OF MATCHING METHOD USED AND REGISTERD DATA
END

FIG-13

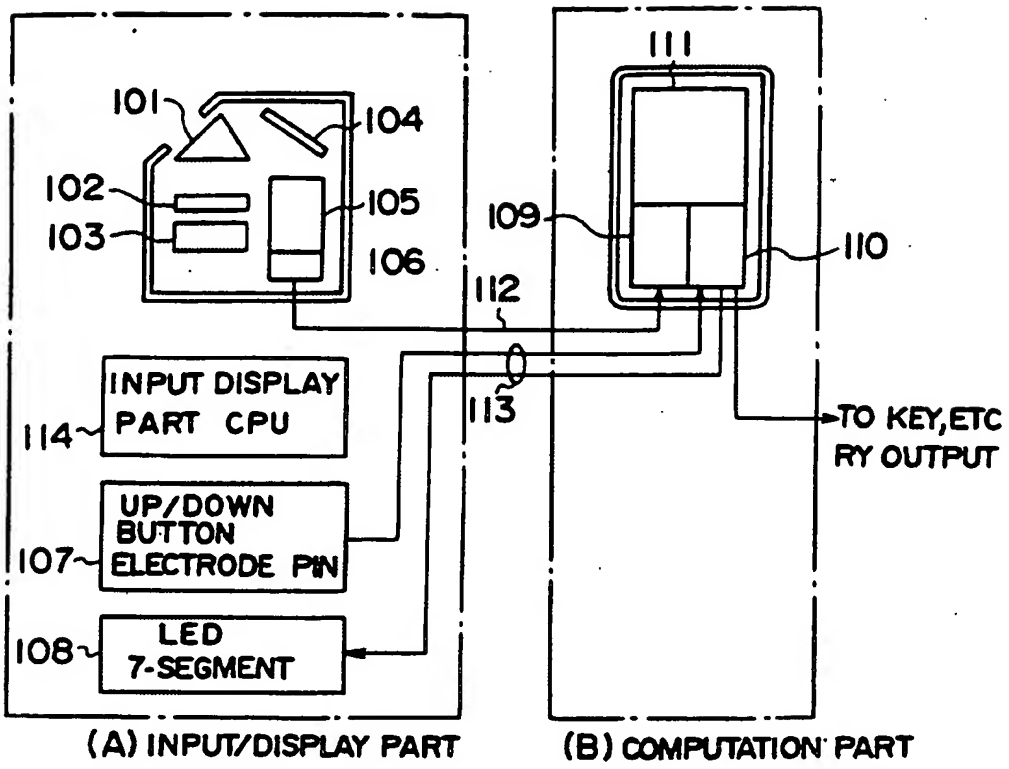

101
104
102
105
103
106
111
109
110
112
113
INPUT DISPLAY PART CPU
114
UP/DOWN BUTTON ELECTRODE PIN
107
LED 7-SEGMENT
108
TO KEY,ETC RY OUTPUT
(A) INPUT/DISPLAY PART
(B) COMPUTATION PART

FIG-14

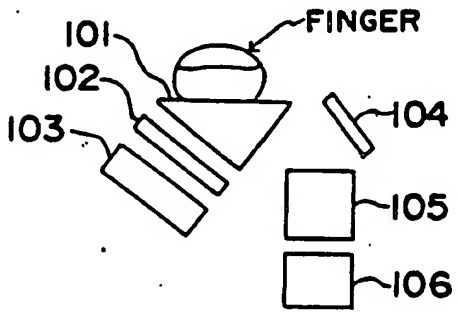

FINGER
101
102
103
104
105
106

FIG-15

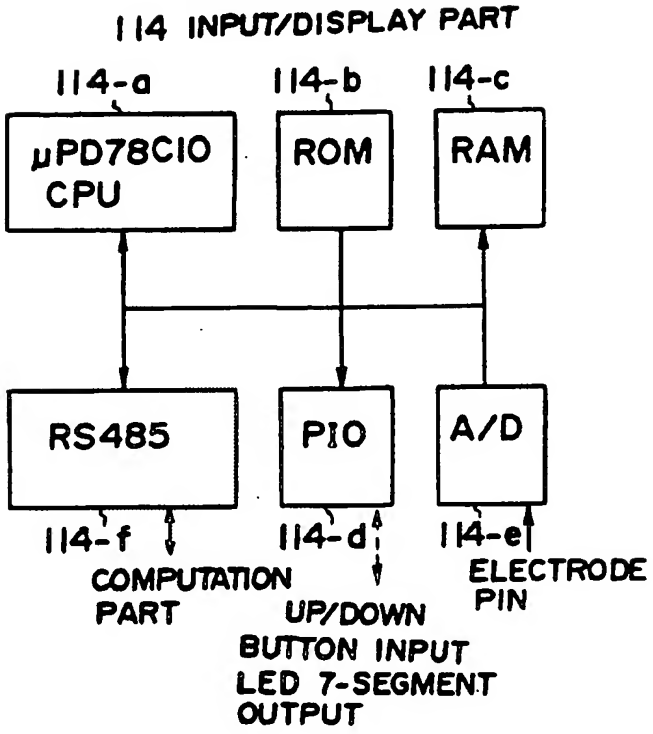

114 INPUT/DISPLAY PART
114-a
114-b
114-c
μPD78C10 CPU
ROM
RAM
RS485
PIO
A/D
114-f
114-d
114-e
COMPUTATION PART
UP/DOWN BUTTON INPUT LED 7-SEGMENT OUTPUT
ELECTRODE PIN

FIG-16

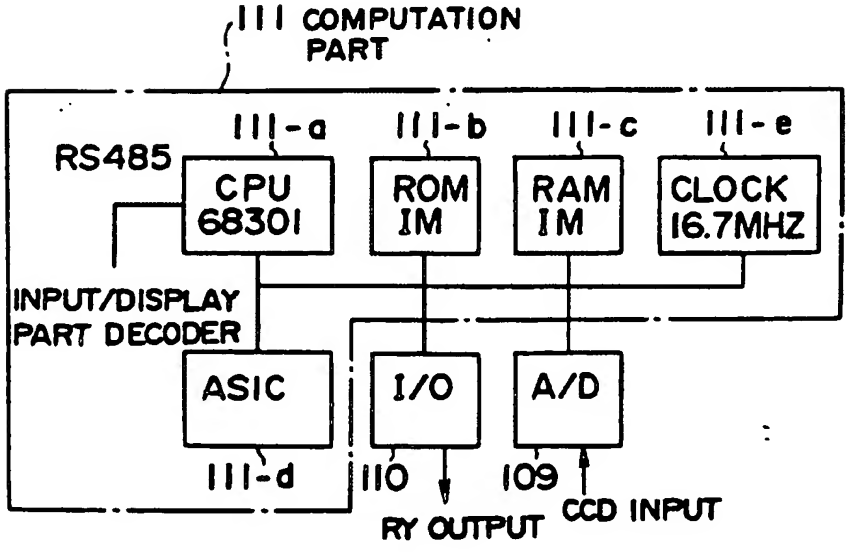

111 COMPUTATION PART
RS485
111-a
111-b
111-c
111-e
CPU 68301
ROM IM
RAM IM
CLOCK 16.7MHZ
INPUT/DISPLAY PART DECODER
ASIC
I/O
A/D
111-d
110
109
RY OUTPUT
CCD INPUT

FIG-17

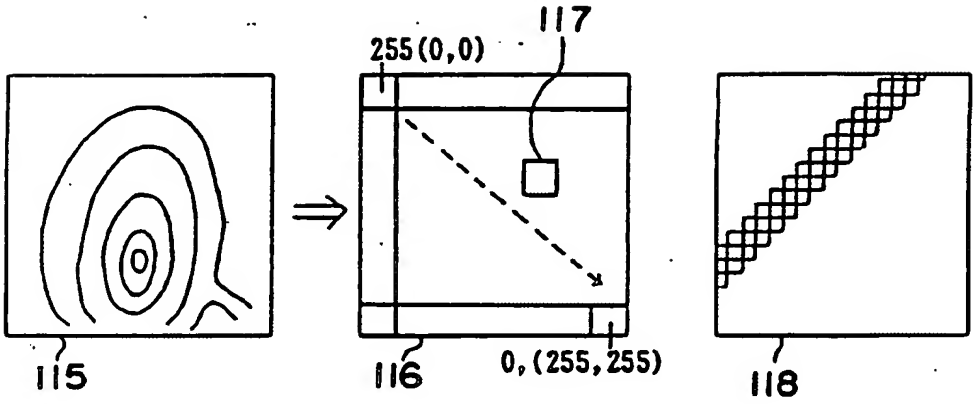


Fig.18

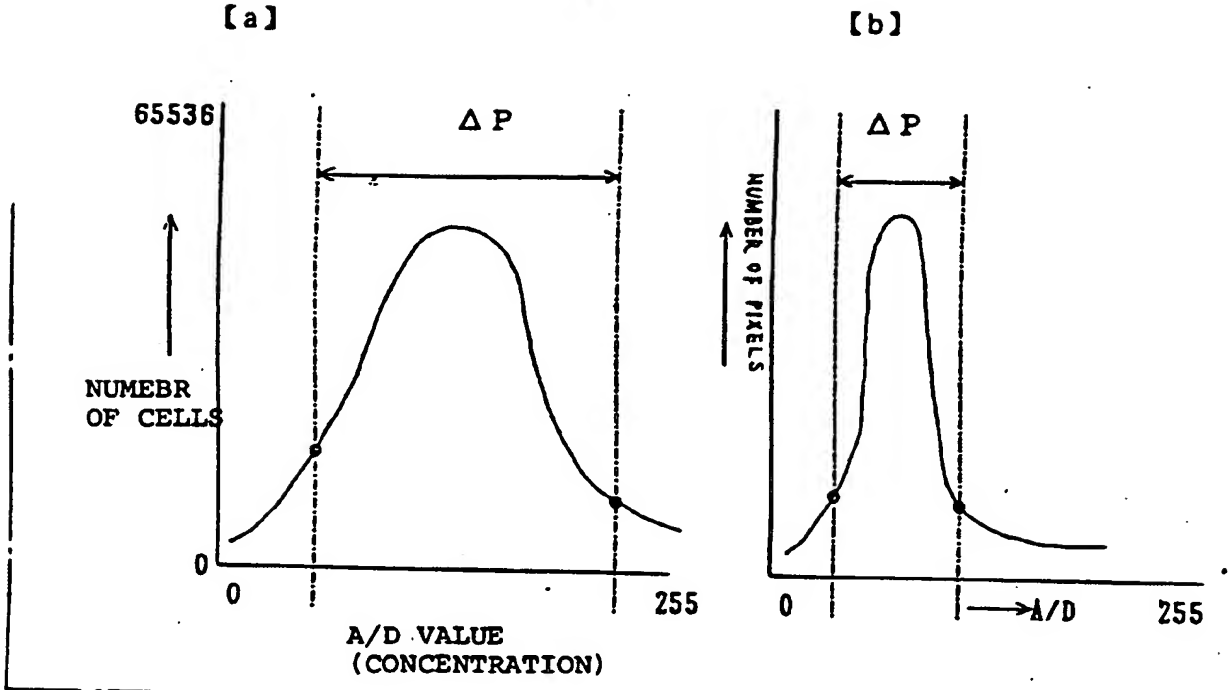

[a]
65536
ΔP
NUMEBR
OF CELLS
0
0
255
A/D VALUE
(CONCENTRATION)
[b]
ΔP
NUMBER OF PIXELS
0
A/D
255

Fig.19

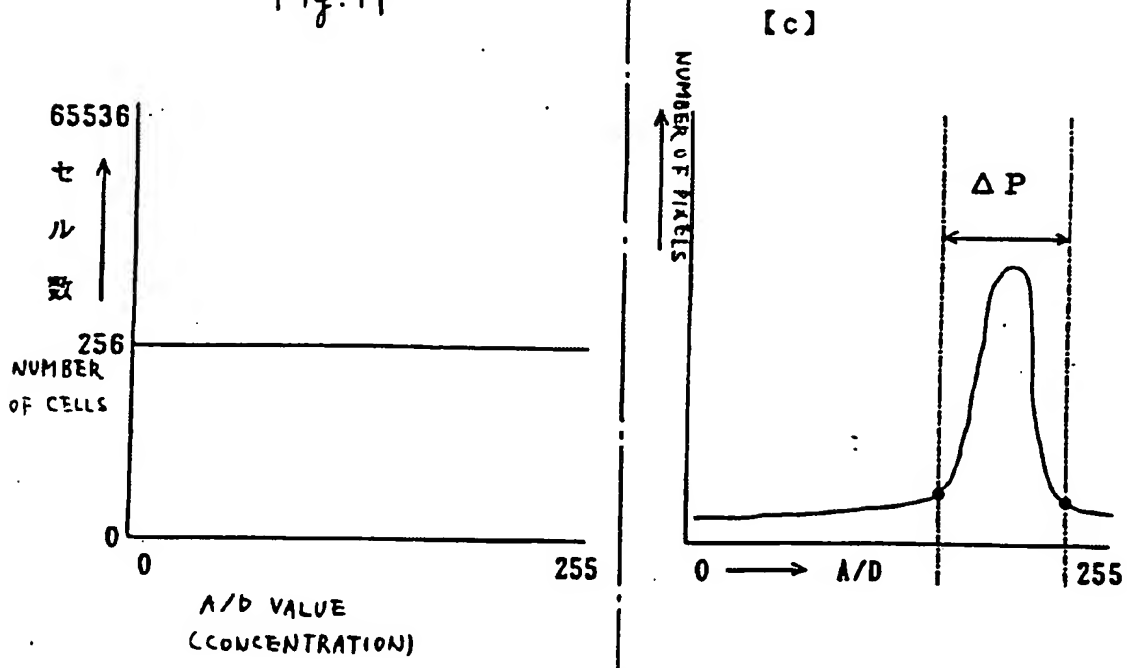

65536
セ
ル
数
256
NUMBER
OF CELLS
0
0
255
A/D VALUE
(CONCENTRATION)
[c]
NUMBER OF PIXELS
ΔP
0
A/D
255

Fig. 20

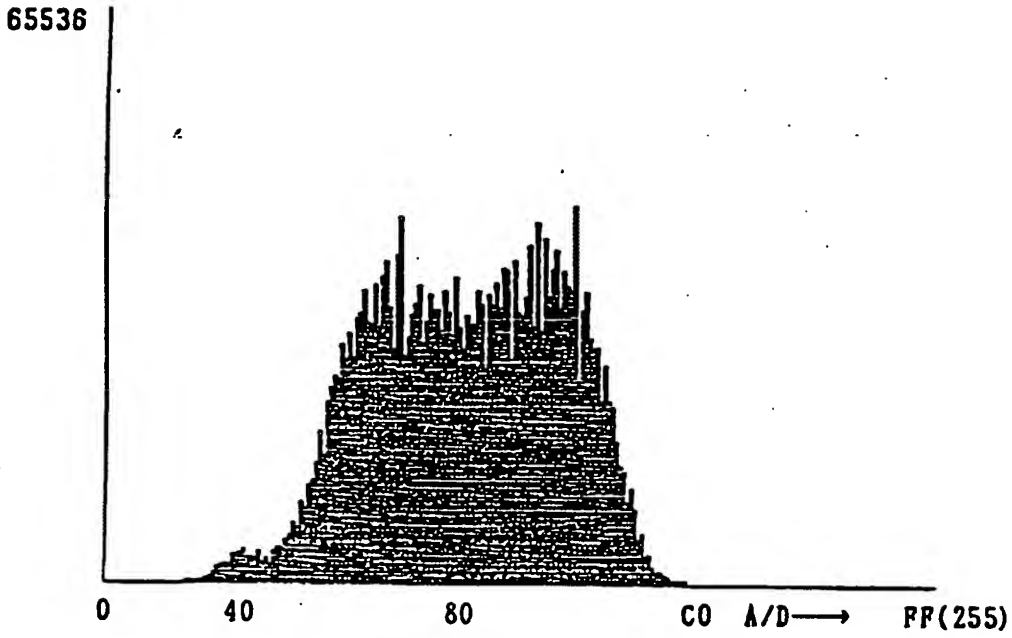

65536
0
40
80
C0
A/D⟶
FF(255)

Fig. 21

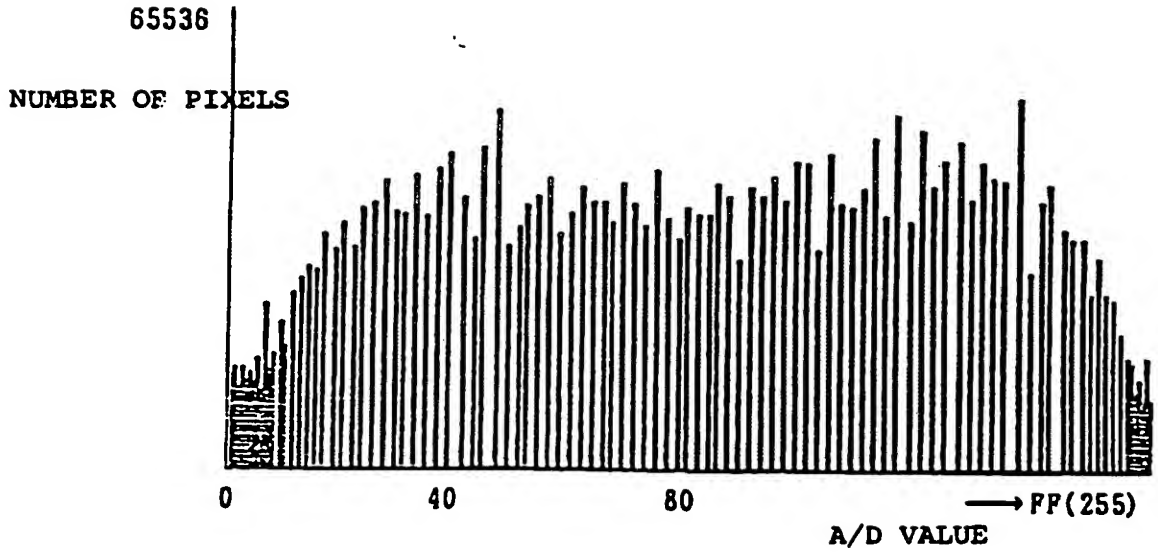

65536
NUMBER OF PIXELS
0
40
80
⟶FF(255)
A/D VALUE

Fig. 22

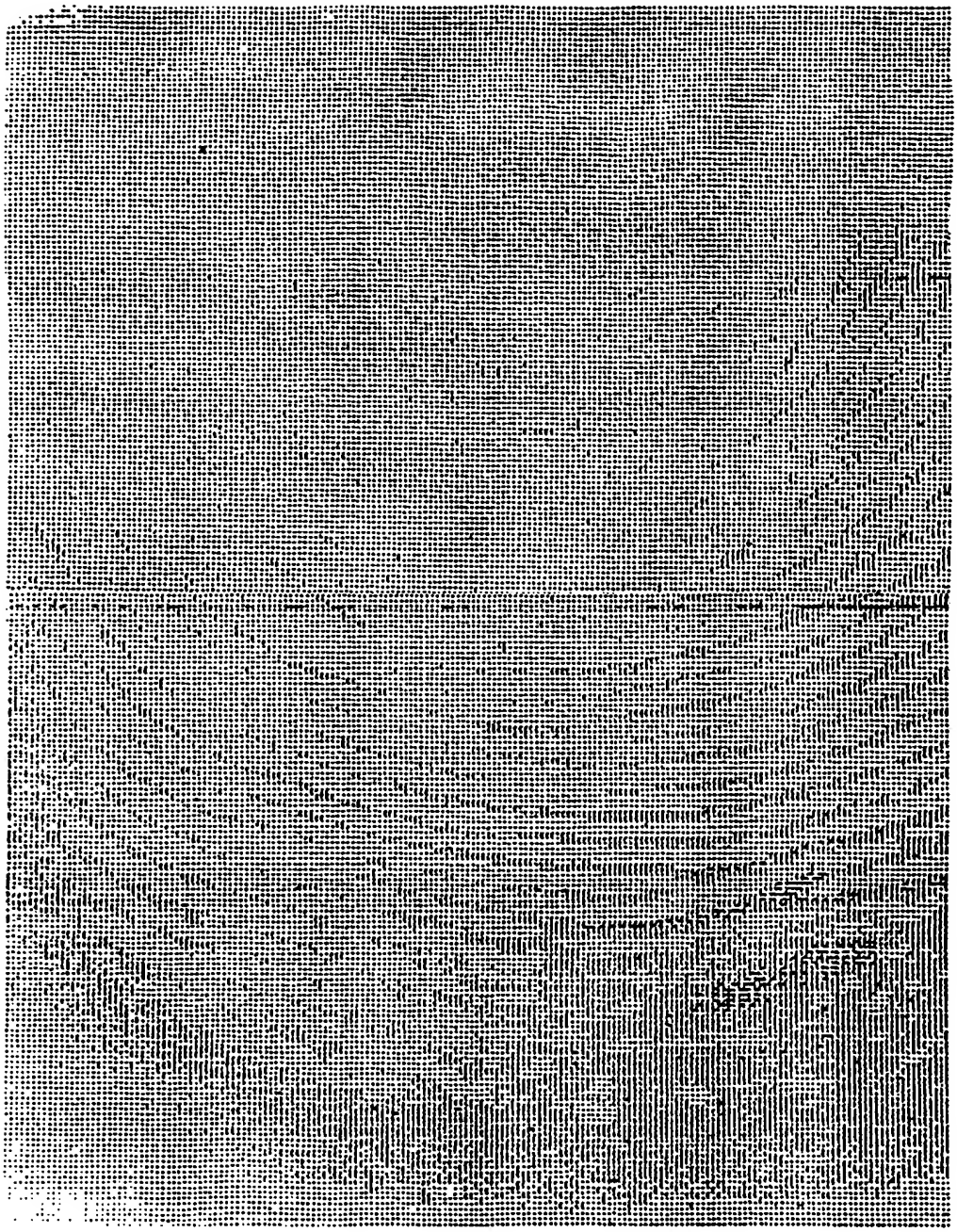
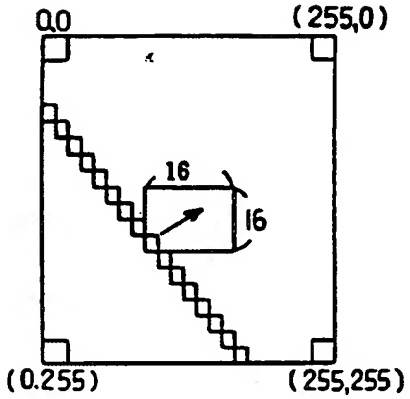


Fig. 23

Fig.24



d= DIRECTION

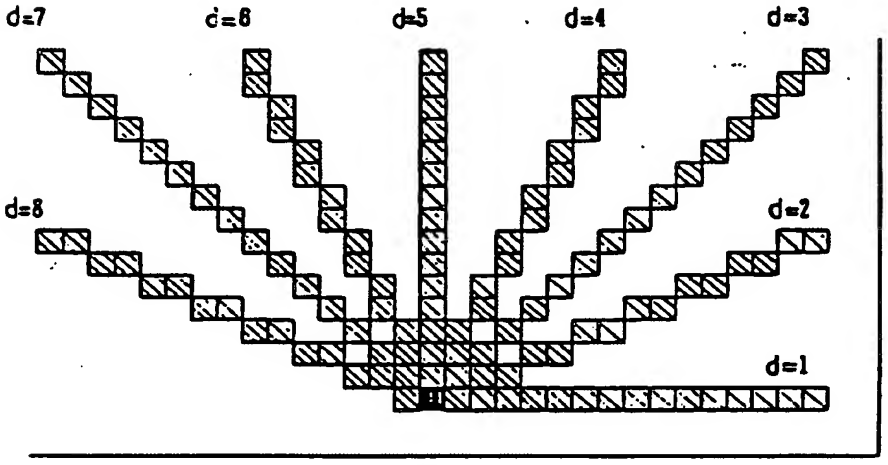


Fig.25-a

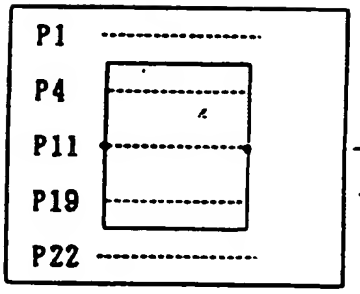


Fig.25-b

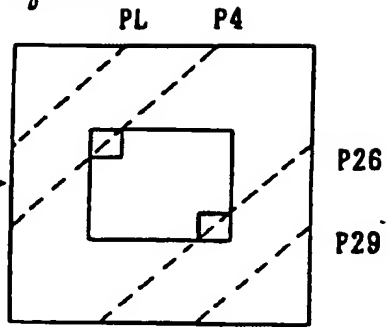


Fig.25-c

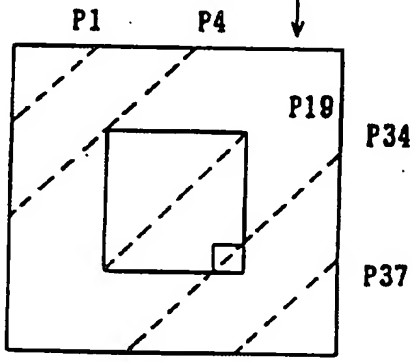


Fig.26

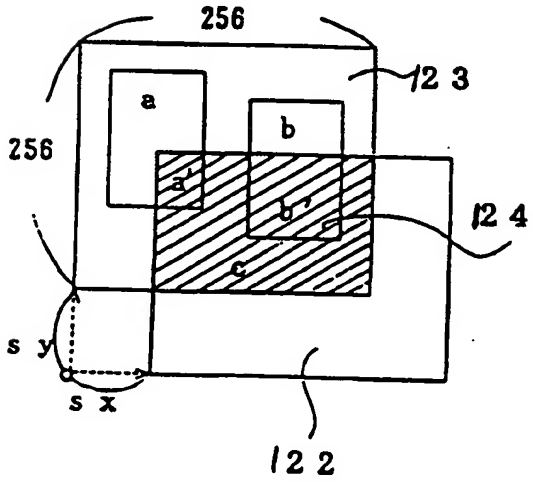


TABLE I

CURVATURE OF CENTRAL AREA (I,J): $K(I,J)=\sum_{L=1}^{8} T(L)$

WHERE

I-1,J-1	I-1,J	I-1,J+1
I ,J-1	I ,J	I ,J+1
I+1 ,J-1	I+1,J	I+1,J

$T(1)=|G(I-1,J-1)-G(I-1,J+1)|$

$T(2)=|G(I-1,J+1)-G(I+1.J+1)|$

$T(3)=|G(I+1,J+1)-G(I+1,J-1)|$

$T(4)=|G(I+1,J-1)-G(I-1,J-1)|$

$T(5)=|G(I-1,J\ )-G(I\ ,J+1)|$

$T(6)=|G(I\ ,J-1)-G(I+1,J\ )|$

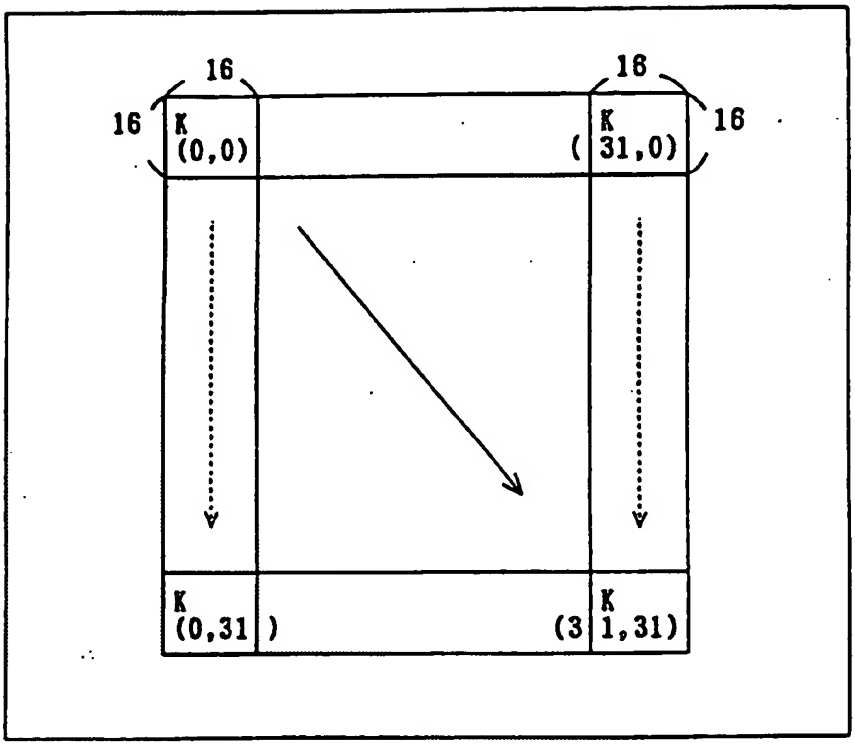
$T(7)=|G(I+1,J\ )-G(I\ ,J+1)|$

$T(8)=|G(I\ ,J-1)-G(I-1,J\ )|$

WHERE G(I,J) IS DIRECTION OF AREA (I,J) AND T(L) IS ABSOLUTE VALUE OF DIFFERENCE IN DIRECTION

$$T(L)=\begin{cases} T(L) : T(L)\leq 4 \\ 8-T(L) : T(L)>4 \end{cases}$$

TABLE 2



TITLE OF THE INVENTION

FINGERPRINT ID SYSTEM AND METHOD

BACKGROUND OF THE INVENTION

The present invention relates to a fingerprint ID system and method which permits real-time comparison of fingerprint image data with previously stored image data.

Fingerprints are utilized as most reliable means to identify individuals because of two outstanding characteristics that they remain unchanged all through life and differ from individual to individual. The features that are used for ingerprint identification are a break point (or end point) of a bulge line (a convexity of a fingerprint pattern) and a point where the bulge line branches (a branch point); these features are generically called minutiae. Since the matching of a fingerprint as an image is encountered with difficulties in the file capacity and matching speed, the fingerprint identification is carried out using the positional relationship of features or minutiae that are extracted from the fingerprint image. The extraction of minutiae from the input fingerprint image begins with the correction of the original image by smoothing and emphasizing, followed by detecting the orientation of the fingerpring pattern. A binary bulge line image is formed by local two-dimensional differential filtering and threshold processing on the basis of the detected orientation. The bulge line image is subjected to thinning processing to detect the positions of minutiae and the direction of the bulge line is measured for each

minutia. Furthermore, the number of intersecting bulge lines is detected as the relationship between neighboring minutiae, by which the position coordinate of each minutia, the pattern orientation and the relationship between neighboring minutiae are listed. The input fingerprint is compared with the previously registered fingerprint by checking individual minutiae of the former against those of the latter.

There has been proposed a fingerprint ID system of the type that compares in real time the input fingerprint image data with registered data to identify individuals. This fingerprint ID system uses a general-purpose microprocessor to perform pre-processing for removing noise from the input image, binary processing for converting the pixel value of image data to a binary value "1" or "0" through use of a predetermined threshold value, thining processing for extracting a figure of the same line width from the binary image, processing for extracting minutiae and pattern matching. In other words, the microprocessor performs the whole image processing.

In the conventional fingerprint ID system, however, image processing for fingerprint identification is carried out exclusively by the general-purpose microprocessor; hence, the processing time increases in proportion to the amount of data to be processed and the complexity of processing, slowing down the system's response in the fingerprint identification.

That is, in image processing by computer software, for example, when 512- by 512-pixel image data is processed for thinning by sequentially scanning it in 3- by 3-pixel blocks, the image data is scanned 510 by 510 times. In the thinning process for extracting a figure of binary image data as a line figure of the same line width without impairing its continuity, it is necessary that: the line width be kept constant; the line be positioned at the center of the original figure; the continuity of the figure be maintained; and end points of the figure not be reduced. In addition, processing is needed to suppress the generation of whiskers in concave and convex portion of the fingerpring between bulge lines and at their intersections. Thus, an appreciably large number of processing steps are involved in the entire image processing.

The above-mentioned scanning for thinning is repeated until it converges all over the display image. Hence, the reduction of the response time of the fingerprint ID system calls for improving the thinning scheme and the hardware configuration therefor.

By mounting hardware exclusive for image processing, the response time could be shortened, but it is undesirable to incorporate such hardware in the fingerprint ID system which is consumer products required to be low-cost and small-sized and the mounting hardware exclusive for image processing is inferior to software processing by a computer in terms of system extensibility.

Besides, the prior art fingerprint ID system utilizes either one of minutia matching and template matching schemes. The minutia matching scheme is excellent in that it ensures stable matching even if the fingerprint to be examined becomes misaligned by rotational movement, but all fingerprints do not have clear minutiae and bulge lines may sometimes be totally flat or unclear. In such a situation, the template matching scheme may provide a higher rate in recognition. That is, the fingerprint ID system of the type using the minutia matching scheme alone cannot always acheive a high success rate in recognition.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a fingerprint ID system and methode which permit high-speed matching of fingerprints while keeping a high recognition rate.

Another object of the present invention is to provide a low-cost, small-sized fingerprint ID system and a method therefor.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram illustrating the hardware configuration of an embodiment of the present invention;

Figure 2 is a schematic diagram showing the positional relationships of respective pixels in a 3- by 3-pixel matrix;

Figure 3 is a table adjoining point pattern index values for which the center pixel in the pixel matrix is deletable;

Figure 4 is a flowchart for a thinning process;

Figure 5 is a table showing adjoining point pattern index values of eight adjoining cells of the pixel matrix at an intersection, a branch point and an end point of bulge lines;

Figure 6 schematically shows patterns of the eight neighboring cells at the intersection, branch point and end point;

Figure 7 schematically shows examples of pseudo minutiae;

Figure 8 is a diagram schematically shows, by way of example, relationships of a master branch point, sub-branch points and sub-sub-branch points;

Figure 9 is a schematic diagram showing the polar coordinate system of the master branch point in Fig. 8;

Figure 10 is a flowchart for minutia matching;

Figure 11 is a schematic diagram showing reference areas for template matching;

Figure 12 is a flowchart for the registration of a fingerprint according to the present invention;

Figure 13 is a block diagram illustrating the principal part of another embodiment of the present invention;

Figure 14 is a schematic diagram explanatory of the operation of the Fig. 13 embodiment;

Figure 15 is a block diagram showing an input display part in the Fig. 13 embodiment;

Figure 16 is a block diagram showing a computation part in the Fig. 13 embodiment;

Figure 17 schematically shows fingerprint data captured

in the compuration part;

Figure 18 shows histograms representing the number of pixels;

Figure 19 is a histogram showing the number of cells;

Figure 20 is a histogram showing input data intact;

Figure 21 is a histogram of the input data subjected to distribution processing;

Figure 22 is a display image of a fingerprint of the input data before being subjected to distribution processing;

Figure 23 is a display image of the fingerprint of the input data after being subjected to distribution processing;

Figure 24 schematically shows slit-like windows;

Figure 25 shows diagrams explanatory of the operation of the Fig. 13 embodiment; and

Figure 26 is a diagram for explaining the comparison of a bulge-line direction pattern and its curvature pattern.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figs. 1 through 12 are diagrams explanatory of the fingerprint ID system and method according to an embodiment of the present invention, which compare fingerprint image data with registered or previously stored image data in real time.

Fig. 1 illustrates in block form the fingerprint ID system, which is indicated generally by 10. The fingerprint ID system 10 comprises a fingerpring image input device 11, an A/D converter 12, a frame memory 13 for storing image data, an image processor 20, a read-only memory 21 for storing adjoining point pattern index values which are used for scanning for thinning, a read-only memory 22 which is used for scanning for the extraction of features or minutiae, a memory 23 for storing control information of scanning for thinning, a memory 41 for storing registered data, an input device 42, an output device 43, an access control signal generator 44 and a central processing unit (CPU) 40.

The fingerprint image input device 11 is made up of a sheet of transparent glass on which to place a finger under test, a light source for illuminating a fingerprint uniformly, a lens through which reflected light passes to create an image, and a CCD area sensor. The video output signal from the CCD area sensor is sampled by the A/D converter 12, whose output digital code is transferred to and stored in the frame memory 13.

The image processor 20 is provided with a digital signal

processor (DPS) which performs sum-of-product and vector calculations at high speed and which is connected via a bus to the read-only memories 21 and 22 for high-speed image processing. The read-only memory 21 has stored therein adjoining point pattern indexes for thinning table search and the read-only memory 22 adjoining point pattern indexes for feature or minutia table search.

The input device 42 is a device through which a password and a command for modifying or deleting registered data in a registering or checking process. The output device 43 is one that outputs comparison results in human-readable form; this device may be a display or audio output device, or a printer. The central processing unit (hereinafter referred to as a CPU) 40 controls at least the input and output devices 42 and 43 and the access control signal generator 44 and conducts image data management and hysteresis management in the registration and comparison processes. The access control signal generator 44 includes a control signal generator which generates a control signal for opening or closing a door, for example, on the basis of fingerprint comparison results.

Next, the operation of this embodiment will be described.

Thinning Processing

A detailed description will be given first, with reference to Figs. 2 through 4, of thinning processing which is performed by the fingerpring ID system 10 of the above-mentioned hardware structure. The thinning processing is to extract line information from a block of image data "1." In concrete terms,

when the value of a pixel at a cell of interest is a "1," it is changed to a "0" depending on the pattern of adjoining pixels; the image data is repeatedly scanned and when there is no longer exists in the image data such a cell whose pixel value is changed to a "0," it is determined that the thinning processing has converged and the scanning is stopped.

In the fingerprint ID system 10, eight neighboring cells, that is, eight pixels P_i (where i = 1 through 8) adjoning the center pixel P_0 in a 3- by 3-pixel matrix as shown in Fig. 2, are each assigned, as a weighting factor W_i, the power 2^{i-1} of 2 which is a value corresponding to one of bits 0 through 7 of one-byte data. The total sum, $V_p = \sum_{i=1}^{8} X_i \times W_i$, of values each obtained by multiplying the pixel value X_i (where i = 1 through 8) of every adjoning cell P_i by the weighting factor W_i (where i = 1 through 8) is used as an adjoining cell pattern index value for the central pixel P_0.

Each pixel value X_i of each adjoning cell takes a binary value "0" or "1" and by the weighting factor assignment method, the adjoining cell pattern index value V_p is one byte long and ranges from 0 with bits 0 through 7 being all OFF to 255 with all the bits ON.

The above-mentioned adjoining cell pattern index value is computed for every combination of the eight neighboring cells in the 3- by 3-pixel matrix for which the pixel value at the central cell is changed from "0" to "1" and the respective adjoining cell pattern index values are stored as a thinning table in the memory 21 as shown in Fig. 3.

Next, a description will be given of thinning determination processing whereby it is determined if the pixel at the center of the 3- by 3-pixel matrix, when it is a "1," can be deleted from the screen, without impairing the continuity of the display image, by changing the pixel value at the center from "1" to "0." The adjoning cell pattern index value V_p of the eight adjoining cells is computed and the tinning table is searched for the same value as that V_p. When the same value as the index value V_p is found in the thinning table, the pixel value at the center of the matrix is changed from "1" to "0" and when such a value is not found, the pixel value at the center is held unchanged.

When the same value as the adjoining cell pattern index values of the eight neighboring cells is not found in the thinning table, it is determined that the thinning of the neighboring cell concerned has converged. Where the adjoinning cell pattern index is present in the table and the pixel value of the central cell is changed from "1" to "0," it is determined that the thining of the neighboring cell has not yet converged. Scanning control means, which controls the scanning of the screen on which a predetermined region of the input image data is being displayed, sequentially scans the screen while shifting the center cell of the eight beighboring cells one by one. This sequentialy scanning takes place until no deletable pixel point is found.

Figure 4 is a flowchart for the thinning process. When the scan for thinning is started in step S1, the screen scan

is initialized in step S2, after which a first step of screen scanning is performed in step S3. That is, in step S3A the thinning of the eight neighboring cells is carried out and in step S3B it is determined if the thinning has converged. If the thinning has not converged, flow proceeds to step S3C wherein a thinning convergence flag is set and its positional information is registered and thence to step S3D wherein it is determined if the thinning has shifted by one pixel or has been completed for one line. When the thinning of the eight adjoining cells has converged, flow proceeds to step S3D, and if it is determined that the thinning has not completed for one line, then flow goes back to step S3A until processing of one line is complete. In step S4, it is determined if thinning convergence flags are all OFF on the line, and if so, the thinning process ends, and if even one of the flags is ON, second and subsequent steps of screen scanning is started in step S5. This is followed by step S6 wherein the scanning is started at the line where the thinning convergence flag is ON, then by step S7 wherein the scanning skips to a registered neighboring cell. Then, in step S8 the thinning process is performed for each of the eight adjoining cells, after which the thinning convergence flags and their pixel positions are updated in step S9. Next, it is determined in step S10 if the thinning convergence flags on the lines of the screen are all OFF, and if even one of the flags is ON, flow proceeds to step S11 wherein it is determined if the number of repetions of the scanning is

is greater than a predetermined value; if so or when the thinning convergence flags are all OFF in step S10, flow comes to an end, and if not, flow returns to step S5, repeating the above-described processing.

As described above, according to the fingerprint ID system 10, in at least the first screen scanning after resetting thinning scan control information, the screen is scanned line by line from the top left-hand corner to the bottom right-hand corner thereof while shifting the center cell of the cell matrix for each pixel. Scan control information for thinning is computed for each line in this screen scanning and prestored in a memory. This control information is composed of: a thinning convergence flag that is set when the line contains an adjoining cell for which the thinning does not converge; the positional information of that adjoining cell in the line; and the number of continuous pixel points for which the thinning does not converge.

When the scanning of the image data is complete, if the thinning convergence flags of the scanned lines are all OFF, it is determined that the thinning process of the screnn has converged; then, the scanning is stopped. When at least one thinning convergence flag is ON on the scanned lines, the image data is scanned again. In this instance, the above-said scan control information stored during the previous scanning is used to start the scanning on the line where the thinning convergence flag is ON and at the first one of the pixel points for which the thinning has not converged. On

each line the display data is scanned for each pixel of every 3- by 3-pixel matrix and it is determined if the pixel point is deletable, updating the scan control information for each line. When the thinning of all adjoining cells on the scanned line has converged, the convergence flag of the line is reset. When there exists in the line a sequence of contiguous pixel points for which the thinning has not converged, the scanning skips them on that line. The scanning of the screen for thinning is repeated until the convergence flags of all lines go OFF, or by a predetermined number of times.

Extraction of Minutia

Next, a description will be given, with reference to Figs. 5 through 7, of minutia extraction processing in the fingerprint ID system 10. Adjoining cell pattern indexes of the eight neighboring cells, which represent intersections, branch points and end points, are prestored in a look-up table. The adjoining cell pattern indexes are computed in units of eight adjoining cells over a predetermined area of the image data processed for thinning, and the look-up table is serached for each of the adjoining cell pattern indexes. When it is found in the table, its coordinates are stored in a memory as a candidate for each of the intersection, branch point and end point. For instance, the adjoining cell pattern index is determined to represent the intersection in the case where the center pixel value surrounded by the eight adjoining cells is a "1" and the adjoining cell pattern index value

is 170 or 85.

When a pair of minutiae of the same kind are close to each other, it is determined that they are pseudo minutiae by noise, and they are deleted from the memory and then true minutiae are extracted. The directions of the respective minutiae of the same kind are determined and, in this case, if their directions are the same and the distance between them is smaller than a predetermined value, then they are determined to be pseudo minutiae.

Figure 7A shows pseudo intersections when the distance between them is short; this is deleted as a bridge from the candidate for the intersection minutia. Figure 7B shows a pseudo branch point caused by perspiration, for instance; the branch point pair is removed from the candidate for the branch point minutia. Figure 7C shows a pair of end points very close to each other; this is regarded as a breakpoint in a line caused by noise and is removed from the candidate for the end point minutia.

Registration of Minutiae

Turning mow to Fig. 8, according to the fingerprint ID system 10, a branch point closest to the center point in the scanned region of the image data is chosen as a master branch point M1. Then, a branch point nearest the master branch point in each of firt through fourth quadrants with the master branch point at the origin of XY coordinates is selected as a sub-branch point m_i (where i = 1 through 4). Next, four branch points are selected as sub-sub-branch points

m_{ij} (where i, j = 1 through 4) in an increasing order of distance to the sub-branch point in each quadrant. In this way, a total of 21 branch points are selected as shown in Fig. 8.

Minutia registration data is composed of: the total number of branch points; their positional addresses; relational data which represents the positional relationship between the master branch point M1 and the sub-branch point m_i in terms of polar coordinates; and relational data which represents the positional relationship between the sub-branch point m_i and the sub-sub-branch point m_{ij}. The relational data for the master branch point M1 and the sub-branch point m_i is polar coordinate data which is composed of the distance r_i between the master branch point M1 and the sub-branch point m_i and the angle θ_i of the sub-brnach point m_i counterclockwise to the bulge-line direction of the master branch point M1 indicated by the arrow in Fig. 9. Incidentally, the bulge-line direction of the master branch point M1 is determined by obtaining binary image data for each processed region with use of an eight-directional filter as is well-known in the art. The positional relationship between the sub-branch point and the sub-sub-branch point is represented by polar coordinate data composed of the distance between them and the angle θ of the direction of the sub-sub-branch point with respect to the bulge-line direction of the master branch point.

Comparison Processing

Next, a detailed description will be given of the process

for comparing features or minutiae of fingerprint image data with registered or previously stored image data. Figure 10 is a flowchart for the minutiae comparison processing.

When the comparison is started in step S20, it is determined in step S21 whether the difference in the total number of branch points between the data to be checked and the registered data is smaller than a predetermined number. If not, it is determined in step S22 that the examinee is an outside, and the process of this flow ends. When the above-mentioned difference in the total number of branch points is smaller than the predetermined value, it is determined that the examinee is not an outsider, after which a maser branch point candidate of the data to be checked is selected in step S23 and the candidate is set as the origin of XY coordinate system in step S24. Then, four sub-branch points are selected in the first through fourth quadrants in step S25 and, in step S26, it is determined if three or more sub-branch points are in a predetermined area around the registered branch point. If three or more sub-branch points are in the predetermined area around the registered branch point, the degree of mismatch between them is computed on the basis of the norm in step S27, then in step S28 sub-sub-branch points are chosen for each sub-branch point, and it is determined in step S29 if three or more sub-sub-branch points are present in a predetermined area around each registered branch point. When three or more sub-sub-branch points are found within the predetermined area, flow proceeds to step S30 wherein the

degree of mismatch between the sub-sub-branch point and the registered sub-sub-branch point is computed, after which an average mismatching degree is computed in step S31. Then, flow proceeds to step S32.

On the other hand, in the event that three or more of the sub-branch points are not found within the predetermined area around each registered branch point in step S26, flow proceeds to step S33 wherein the average mismatching degree of the sub-sub-branch points is set to 100, followed by step S32. When three or more of the sub-sub-branch points are not found within the predetermined area around each registered branch point in step S29, the average mismatching degree of the sub-sub-branch points is set to 120 in step S34, then flow proceeds to step S31.

In step S32 it is determined if the number of master branch point candidates selected is larger than a predetermined value; if so, flow proceeds to step S35, and if not, flow returns to step S23, repeating the above-described processing. In step S35 the master branch point to be checked is selected which provides the minimum average mismatching degree, then in step S36 it is determined if the average mismatching degree of the master branch point is smaller than a predetermined value; if so, it is determined in step S37 that the examinee is not an outsider, and if not, it is determined in step S38 that the examinee is an outsider, the process of this flow comes to an end.

By the above flow, the total number of branch points,

their positional addresses and relational data are extracted for the data to be checked, as is the case with the registered data. It is made sure that the absolute value of the difference between the total number of extracted branch points and the total number of branch points in the previously registered data selected for comparison is smaller than a predetermined value TH1. When the absolute value is greater than the value TH1, it is judged that there is no identity between the data to be checked and the registered data, i.e. that the examinee is an outsider.

When the above-noted absolute value is smaller than the value TH1, the branch point closest to the center of the data to be checked is selected as a master branch point candidate M'1 and it is determined if sub-branch points m_1, m_2, m_3 and m_4 are present in the branch points to be checked, on the assumption that the master branch point candidate M'1 is the master branch point M1 of the registered data. This is carried out in such a manner as described below.

The bulge-line direction of the master branch point candidate M'1 is obtained and it is determined if any branch points exist in a predetermined area around the registered sub-branch point m_i (where i = 1 through 4) of the polar coordinate representation (r_i, θ_i).

More specifically, a check is made to see if the sub-branc point m_i of the branch point to be checked is present in a permissible area $(r_i \pm C_{ri}, \theta_i \pm C\theta_i)$ around the sub-branch point m_i of the registered data. C_{ri} is a given limit of

the afore-mentioned distance r_i and $C\theta_i$ a given limit of the afore-mentioned angle θ_i.

Where two or more of the four sub-branch points m'_i fall outside of the above-said area, the master branch point candidate M'1 is judged as inappropriate, after which the mean value of the mismatching degree of the sub-branch points is set to 100 and processing is performed for the next master branch point candidate as described below. When three or more sub-branch points are found in the respective permissible areas, the mismatching degree is counted as the degree of mismatching.

According to the fingerprint ID system 10, the mismatching degree S_{pi} of the sub-branch point m_i (where i = 1 through 4) is expressed by the following equation using the norms concerning the distance r and the angle θ represented by the polar coordinates. Incidentally, (r_x, θ_x) is a polar coordinate representation of the sub-branch point m'_i for the master branch point candidate of the image data to be checked.

$$S_{pi} = \| r_x - r_i \| \times 40/C_{ri} + \| \theta_x - \theta_i \| \times 40/C\theta_i$$

Also for the sub-sub-branch point m'_{ij} (where i, j = 1 through 4) relative to the sub-branch point m'_i of the image data to be checked, the mismatching degree S_{pi} is similarly expressed by the following equation using the norms concerning the distance r and the angle θ represented by the polar coordinates. Incidentally, (r_{xx}, θ_{xx}) is the polar coordinates of the sub-sub-branch point m'_{ij} relative to the sub-branch point m'_i. (r_{ij}, θ_{ij}) is the polar coorinate

representation of the position of the sub-sub-branch point m_{ij} of the registered data relative to the sub-branch point m_i.

$$S_{pij} = \| r_{xx} - r_{ij} \| \times 50/C_{rij} + \| \theta_{xx} - \theta_{ij} \| \times 50/C\theta_{ij}$$

The reason for which the weight of the mismatching degree S_{pij} of the sub-sub-branch point m'_{ij} (where i, j = 1 through 4) is made 20% larger than the mismatching degree S_{pi} of the sub-branch point m'_i (where i = 1 through 4) is that importance is attached to the relationship that the sub-sub-branch point m'_{1j} matches the registered sub-sub-branch point when the sub-branch point m'_1 of the data to be checked matches the registered sub-branch point m_1.

In the matching of the branch points of the image data to be checked with those of the registered data, if the branch points of the data to be checked are not found in the respective permissible areas, then the mismatching degree of the sub-branch points to be checked is set to 100 and the mismatching degree of the sub-sub-branch points to be checked is set to 120. In this instance, however, if the sub-branch point m'_i (where i = 1 through 4) does not satisfy the condition that it is present in the first through fourth quadrants with respect to the master branch point M'1 of the data to be checked, the sub-branch point will be ignored in the calculation of the mean mismatching degree. Similarly, the sub-sub-branch point m'_{ij} is also ignored in the computation of the mean mismatching degree unless it is present in the quadrant where the sub-branch point m'_i exists.

When two or more sub-sub-branch points m'_{ij} (where i, j = 1 through 4) do not fall inside of the respective permissible areas of the sub-branch points m'_i (where i = 1 through 4), the mean mismatching degree is set to 120.

A value obtained by dividing the sum total of the mismatching degree of the sub-branch points m'_i (where i = 1 through 4) and the mismatching degree of the sub-sub-branch points m'_{ij} (where i, j = 1 through 4) by the number of branch points invlved is used as the mean mismatching degree of the master branch point candidate M'1 of the date to be checked.

A predetermined number of master branch point candidates M'1 are selected in the increasing order of the distance to the center of the display data, then the mean mismatching degree of each master branch point candidate M'1 is computed, and then the candidate M'1 which provides the lowest mean mismatching degree is used as the master branch point M'1 of the data to be checked. In this instance, however, only when the mean mismathcing degree of the master branch point candidates M'1 is revised downward, the mean mismatching degree of the sub-sub-branch points m'_{ij} (where i,j = 1 through 4) with respect to the sub-branch points m'_i (where i = 1 through 4) is computed. This method is used to shorten the processing time. When a value obtained by dividing the sum total of the mismatching degrees of the sub-branch points m'_i (where i = 1 through 4) by the number of sub-branch points is smaller than a predetermined threshold value, it is judged that the features or minutiae of the data to be checked are identical

with those of the registered data, that is, the examinee is identified as the person of the registered data.

In the registration of data for template matching, as shown in Fig. 11, a 128- by 128-pixel reference area A is provided around the center of binary image data and 64- by 128-pixel reference areas B and C are provided right- and left-hand sides of the reference area A; image data with these reference areas compressed to 1/4 is used as registered data. By the compression of the reference areas to 1/4, the image data is broken up into cells each consisting of four pixels. These cells are each represented by a "1" or "0" depending on whether two or more pixel values are "1" or "0." Then, the numbers of pixel values "1" in respective 8 x 8 = 64 sections, each consisting of 48 x 48 pixels, are counted and these numbers are registered as gradation or gray scale distribution data.

The template matching of binary data begins with the alignment of the X- and Y-axes of the display image to be matched and the registered one. For this alignment, the above-mentioned gradation or gray scale distribution data is used to detect an error or displacement (K, L), which is obtained by counting the number of pixel values "1" in the 64 sections of each data, the number thus obtained for the data to be matched with the registered data being identified by A(i, j) and the number for the registered data by B(i, j) (where i, j = 1 through 8). A deviation S(K, L) is obtained by the following equation, for example, and 255 deviations

are calculated.

$$S(-7, 0) = \frac{\sum_{j=1}^{8} A(8, j) - B(1, j)}{48 \times 8}$$

$$S(-6, 0) = \frac{\sum_{p=1}^{2} \sum_{i=1}^{8} \sum_{j=1}^{8} A(1, j) - B(p, j)}{48 \times 8 \times 2}$$

The displacement (K, L) which provides the minimum deviation is obtained. At first, the display image A' to be examined is matched against the registered display image A every five pixels about the above-noted displacement (K, L) and the position coordinate is obtained which provides the minimum difference between the both display images A' and A which is expressed by the number of exclusive ORs "1." Next, the difference between the both display images A' and A is computed every pixel around the above-noted position coordinate and the difference thus obtained is used as a displacement to obtain the position of the minimum difference.

The display image to be examined is shifted in parallel by the amount of the above-mentioned displacement and the reference area A' is matched against the counterpart A. When the difference between them is smaller than a predetermined value TH1, the examinee is identified as the person of the registered data, and when the difference is greater than a predetermined value TH2, the examinee is judged as an outsider. When the difference is intermediate between the predetermined values TH1 and TH2, the reference areas B and C shown in Fig. 11 are matched with those of the registered

data; if the differences in the reference areas are smaller than predetermined values TH3 and TH4, respectively, the examinee is judged as the person of the registered data, and if not, he is judges as an outsider.

Referring to Fig. 12, the above will be described more specifically. Figure 12 is a flowchart for the registration of a fingerprint.

A description will be given of the registration of a fingerprint. Fingerprint image data of a 2- by 2-cm area of the finger placed on an image processor is subjected to photo-electric conversion by a CCD area sensor (not shown) of the image input device 11 in Fig. 1 and stored in the frame memory 13 via the A/D converter 12.

The fingerprint image data thus stored in the frame memory is subjected to pre-processing such as smoothing. The smoothing of the image data is carried out by removing noise through use of a filter as is well-known in the art. Then, the image data is converted into binary form. The interpolation of a threshold value, which depends on the area of the binary display image, also utilizes a well-known method.

The binary image is subjected to thinning processing, then features or minutiae of the image data are extracted, and the afore-mentioned data on branch points is registered as minutiae registered data in step S41. Next, the image data is matched against the data to be checked, by a minutiae matching method in step S42 and, for the binary image data, template matching data is registered in a memory in step S43.

The determination of the bulge-line direction of the fingerprint for template matching use utilizes an eight-directional filter as is well-known in the art. The image data stored in the frame memory is template-matched as data to be matched in step S44.

In step S45 the minutiae matching method and the template matching method are compared in terms of the recognition rate. When the template matching method has a higher rate in recognition, it is adopted as the matching method of the finger being examined. When the minutiae matching method is higher in the recognition rate, it is adopted. Then, the registered image data and the matching method therefor are stored in a memory in association with each other in step S46. More specifically, when the fingerpring matching the registered one cannot be identified as being identical by the minutiae matching method, the template matching method is used. With the minutiae matching method, the recognition rate can be quantified through utilization of the ratio between the mean mistching degree and a predetermined value for authenticating the examinee's identity; in the case of the template matching method, the recognition rate can be quantified using the ratio between the afore-mentioned difference and the above-note predetermined value for authenticating the examinee's identity.

Incidentally, the template matching method or minutiae matching method is selected in the fingerprint registration on the basis of data of one screen scanning, but for the

purpose of testing the recognition rate, image data of one frame may be stored in the frame memory. The screen scanning time is about 50 ms; the examinee's finger need not be placed on the image processor again and again and the data for matching can be scanned and stored during one fingerprinting.

In the course of registration, an ID number or password is input as an index of the registerd fingerpring data. In the matching process, the ID number of password is input and then the finger to be examined is placed on the image input device. The ID number serves as an index key to access the registered fingerpring data, speeding up the search for registered data. The ID number that is used in the registration step may common to a plurality of persons forming the same group; in such a case, the data to be examined is matched with a plurality of pieces of registered fingerprint data one after another.

The image processing described above, that is, preprocessing, processing for conversion into binary form, thinning processing, minutiae extration and matching are all performed by a digital signal processor. The adjoining cell pattern index values for eight adjoining cells are computed at high speed by a digital signal processor designed to be suitable for the sum-of-product computation. Alternatively, the adjoining cell pattern index values could be obtained at high speed by a method in which a register of a one-byte bit width is initially cleared, the eight adjoining

cells are squentially scanned when the respective adjoining pixel values are "1," and the bits in the byte corresponding to the respective adjoining cells are turned ON.

While the table search for the thinning determination and for the minutiae extaction is performed by linearly searching memories by the digital signal processor, it may be a binary search; alternatively, it is possible to use a device which is provided with means for accessing the read-only memory by using the adjoining cell pattern index value as a one-byte read address, and in this instance, it is determined if the thinning process is to be performed, according to the read-out contents of the read-only memory. With the look-up table operating method according to the present invention, the machine time for the convergence of the thinning process of a screen composed of about 500 by 500 pixels can be made as short as 30 to 50 ms. The matching response time is as short as around 1 sec.

As will be appreciated from the above, the fingerprint ID system of the present invention permits high-speed processing for thinning the image data and extraction of minutiae in units of eight adjoining cells by the digital signal processor provided independently of the central processing unit; furthermore, the invention achieves a high recognition rate unobtainable with the minutiae extraction method alone and as short a matching response time as one second or so, by the means for matching a fingerprint with no remarkable minutiae through the template matching method. Besides, the

combined use of the digital signal processor and the microprocess offers an economical fingerpring ID system higher in cost performance than a system using a single high-performance microprocessor.

Next, a description will be given of another embodiment of the present invention, which is intended for reduction of the cost of hardware by increasing the amount of data to be processed in the form of software while maintaining the performace of the system at a high level. In order that dry, wet and nonlinear fingerprints may be captured as constant and stable data, automatic contrast control is effected at the time of data input to thereby shorten the processing time and enhance the recognition rate. This embodiment employs a two-stage comparison scheme including a curvature pattern comparison and an extracted minutiae comparison and adopts high-precision thinning process for the extraction of minutiae and, by a unique high-speed algorithm, solves the "long processing time" problem of the thinning scheme so as to reduce the overall processing time and enhance the system performance.

Fig. 13 illustrates in block form the system configuration of this embodiment, which comprises an input/display part (A) and a computation part (B). Light emitted from a light source 103 is diffused by a diffuser 102 and is totally reflected by a prism 101; the fingerprint image therefrom is reflected by a mirror 104 and passes through a lend 5, creating an image on a CCD 105 for conversion into an analog

signal. The analog signal is provided via a cable 112 to an A/D converter 109 for conversion into a digital signal, which is subjected to software processing in a computing part 111 for matching with previously data. When the examinee is identified as the person of the registered data, it is indicated to an interface 110 with the outside.

The light source 102 is selected in accordance with the sensitivity characteristic of the CCD 106 and the diffuser 102 is provided so that no variation is caused in the surface of the prism 101. To make the input part compact, the optical axis is bent by the mirror 104 to provided for increased optical path. The lens 105 is adjusted so that the fingerprint of the ball of a finger pressed against the surface of the prism 101 over an area measuring 16 by 16 mm is formed into an image of the real size uniformly all over the surface of the CCD 106. The CCD 106 obtains data of 256 by 256 pixels from the image and the data is converted by the A/D converter 109, thereafter being captured into the computation part 111 and fed into a CPU 111-a in Fig. 16.

Figure 16 illustrates in block form the computation part 111, which is made up of a 16-bit CPU 111-a, a ROM 111-b, a RAM 111-c, an ASIC very large scale integrated logical circuit 111-d and an oscillator 111-e. The computation part 111 performs high-speed data processing. An input display part 114 shown in Fig. 15 functions as an interface with a user and provides required displays in the cases of inputting, matching and registering data, for instance.

Figure 15 shows the input display part 114, which is comprised of a CPU 114-a, a ROM 114-b, a RAM 114-c, a parallel interface 114-d, an A/D converter 114-e and an interface 114-f to the computation part 111.

Figure 17 shows an example of fingerprint data captured into the computation part 111. The fingerprint data is composed of 256 x 256 pieces of data, each of which forms 8-bit data and takes values from 0 to 255, 0 representing the darkest part of the fingerprint and 255 the lightest part. In other words, the dark-and-light pattern of the fingerprint of a 16- by 16-mm size on the prism 101 is represented by numerical values from 0 to 255 of the 256 x 256 pieces of data. Since the number of bulge lines of a man's fingerprint ranges from 2 to 7 per millimeter, one bulje line has an 8 to 3 cell data width.

In general, fingerprint data that is obtained through utilization of the total reflection under automatic contrast control by software processing of the prism surface presents such a concentration histogram as shown in Fig. 18-a. The abscissa represents A/D converted data value (the output signal from the CCD being converted to digital form and stored in a memory); the afore-mentioned A/D converter 106 is an 8-bit high-speed A/D converter and the data varying range covers 256 gradations (0 to $FF = 0 to 255). The ordinate represents the number of cells, which is 256 x 256 = 65536 pixels. Thus, Fig. 18-a is a concentration histogram indicating the number of pixels for each gradation.

In the cases of a dry fingerpring, a wet fingerprint and a fingerprint lacking linearity, the concentration is unbalanced as shown in Figs. 18-b and 18-c and a range indicated by ΔP tends to narrow. By removing such an imbalance of concentration and making it uniform, it is possible to obtain a high-contrast, clear image.

Such input data as shown in Fig. 20 is distributed into such a form as depicted in Fig. 21. As the result of this, a fingerprint depicted in Fig. 22 changes to such as shown in Fig. 23. Fig. 20 is a concentration histogram of the fingerprint shown in Fig. 22 and the image corresponding to the data subjected to the distribution processing, shown in Fig. 21, is shown in Fig. 23. As is evident from comparison of Figs. 22 and 23, the constrast of the image is considerably improved. It has been ascertained experimentally that the fingerprint of Fig. 22, hard to recognize by the prior art, was made recognizable. It has also been proved that satisfactory contrast and uniform data could be obtained by the distribution processing alone, without performing the averaging process.

Since the time for the distribution processing is 1/35 that for the averaging process, this embodiment performs the distribution processing to provide a uniform distribution of concentration to effect automatic contrast control. In this distribution processing, each pixel is represented by $m(xi, yj)$, where (xi, yj) is the pixel position (x coordinate, y coordinate), $i = 0$ to 255. m is the number of each pixel

in ascending order of concentration, that is, in ascending order of powers of (xi, yj). Thus, m takes values from 1 to 65536. Next, m(xi, yj) is converted to [$n = \text{int}\frac{m}{256}$], where $\text{int}\frac{m}{256}$ is a quotient of dividing m by 256; hence, n = o to 255. This n is the concentration at the position (xi, yj) after the distribution processing.

In the computation for the identification of a fingerprint by a curvature pattern, the bulge-line direction is obtained in the binary 256 by 256 area every 16 by 16 subarea through use of slit-like windows such as shown in Fig. 24. In this case, the mean concentration $Ad^{(m)}$ in each window is detected while shifting the window vertically by one pixel at one time.

$$Ad^{(m)} = \frac{1}{16} \sum_{m=1}^{16} gm$$

where d = 1 to 8 and m = 1 to L, L being the number of positions which is determined by the direction d. Next, the mean concentration distribution Vd in the same direction is computed by the following equation.

$$Vd(i) = \frac{1}{L} \sum_{m=1}^{L} \{Ad^{(m)} - \overline{Ad}\}^2, \text{ where } \overline{Ad} = \frac{1}{L} \sum_{m=1}^{L} Ad^{(m)}$$

The direction in which the value Vd is the largest is the bulge-line direction in this area. The number of positions which is determined by the direction d (1 to 8) changes as shown in Figs. 25-a through 25-c.

In Fig. 25-a, when the direction d = 1, data on 22 positions is computed. In Fig. 25-b, when d = 2, data on 29 positions is computed. In Fig. 25-c, when d = 3, data on 37

positions are computed. When d = 4, 6 and 8, the number of positions on which data is computed is the same as in the case of d = 2; when d = 5, data is computed on the same number of positions as in the case of d = 1; and when d = 7, data is computed on the positions of the same number as in the case of d = 3.

As shown in Table 1, 32 x 32 pieces of bulge-line direction data in the 16 x 16 areas are used to compute the curvature of the bulge line in the eight adjoining cells all over the area.

As shown in Table 2, when a background area exists, if one or both of G(m1) and G(m2) are not present, no computation is conducted.

Fig. 26 is a diagram for explaining the comparison of bulge-line direction patterns and bulge-line direction curvature patterns of the data to be examined and the registered data. For this comparison, the data to be registered is converted to binary form and subjected to thinning and the bulge-line direction and curvature in the bulge-line data are computed. Furthermore, the positions and directions of minutiae are computed and stored, and the bulge-line direction and its curvature in the binary data are computed. The bulge-line direction data and curvature data of the data to be examined are matched against those of the registered data to detect the position (sx, sy) where a deviation S(x, y) is minimum. When the matching degree is above an upper threshold value, the examinee is judged to be the person of the registered data, and when the matching degree is under a lower threshold

value, the examinee is judged to be an outsider. The matching degree is obtained on the basis of 32 x 32 = 1024 pieces of bulge-line direction and curvature data. At the above-said position (sx, sy) the differences in direction and curvature are minimum.

Letting the areas of the registered data where many minutiae exist be represented by a and b, areas a' and b' in an area c displaced from that a by (sx, sy) are thinned. The position, kind and direction of each minutia of the data to be examined are checked against those of the registered data; when the matching degree is above the upper threshold value, the examinee is identified as the person of the registered data, and when the matching degree is under the lower threshold value, the examinee is judged to be an outsider. When the matching degree is above the lower threshold value but under the upper one, the area c (except those a' and b') is thinned and minutiae are extracted; then, similar matching is conducted and the examinee is judged in the same fashion as mentioned above. This method does not ever affect the matching accuracy and rate.

Unlike the conventional simple smoothing scheme, the automatic contrast control according to the present invention permits the generation of high-contrast data and effective removal of noise, and hence is very effective pre-processing means for reducing the overall processing time and enhancing the recognition rate. By thinning only those areas containing many minutiae, the matching time is substantially reduced.

CLAIMS:

1. A fingerprint ID method which compares registered fingerprint data and input fingerprint data obtained by automatic contrast control by software, characterized by:

first matching wherein a bulge-line direction pattern and a bulge-line curvature pattern of said registered fingerprint data are compared with those of said input fingerprint data and aligned with each other; the matching degree of said bulge-line direction and curvature patterns in their overlapping areas is computed; when said matching degree is above an upper threshold value, the examinee is judged to be the person of said registered fingerprint data; and when said matching degree is under a lower threshold value, said examinee is judged to be an outsider; and

second and third matching steps wherein when said matching degree is above said lower threshold value and under said upper threshold value, only those areas of said input fingerprint data which match minutia high- and medium-density areas of said registered fingerprint data are subjected to thinning to extract minutiae; the matching degree of said extracted minutiae is computed in terms of their position, kind and direction; when said matching degree in said high-density area is above said upper threshold value, said examinee is judged to be the person of said registered fingerprint data, and when said matching degree is under said lower threshold value, said examinee is judged to be an outsider, and when said matching degree is above said lower threshold value and under said upper threshold value, said examinee is judged to be an outsider; and when said matching degree in said medium-density area is above said upper threshold value, said examinee is judged to be the person of said registered fingerprint data, and when said matching degree is under said lower threshold value, said examinee is judged to be an outsider, and when said matching degree is above said lower threshold value and under said upper threshold value, said examinee is judged to be an outsider.

2. An apparatus for fingerprint ID which compares registered fingerprint data and input fingerprint data obtained by automatic contrast control by software, characterized by:

first matching means for comparing and aligning a bulge-line direction pattern and a bulge-line curvature pattern of said registered fingerprint data with those of said input fingerprint data; means for computing the matching degree of said bulge-line direction and curvature patterns in their overlapping areas; means for judging the matching degree such that when said matching degree is above an upper threshold value, the examinee is judged to be the person of said registered fingerprint data and when said matching degree is under a lower threshold value, said examinee is judged to be an outsider; and

matching means wherein in response to said matching degree being above said lower threshold value and under said upper threshold value, only those areas of said input fingerprint data which match minutia high- and medium-density areas of said registered fingerprint data are subjected to thinning to extract minutiae and the matching degree of said extracted minutiae is computed in terms of their position, kind and direction; wherein in response to said matching degree in said high-density area being above said upper threshold value, said examinee is judged to be the person of said registered fingerprint data, and when said matching degree is under said lower threshold value, said examinee is judged to be an outsider, and wherein in response to said matching degree being above said lower threshold value and under said upper threshold value, said examinee is judged to be an outsider; and wherein in response to said matching degree in said medium-density area being above said upper threshold value, said examinee is judged to be the person of said registered fingerprint data, and wherein in response to said matching degree being under said lower threshold value, said examinee is judged to be an outsider, and wherein in response to said matching degree being above said lower threshold value and under said upper threshold value, said examinee is judged to be an outsider.

3. A fingerprint ID method substantially as herein described with reference to the accompanying drawings.

4. An apparatus for fingerprint ID substantially as herein described with reference to the accompanying drawings.

The Patent Office

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Claims searched:	1 to 4	**Date of search:**	16 June 1997

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G4R(RHB, RRL, RRM, RRP)

Int Cl (Ed.6): G06K 9/00, 9/62, 9/64, 9/66, 9/68, 9/78, 9/80, 17/00; G07C 9/00

Other: Online:WPI, INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US 5105467 (KIM), see abstract	-

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